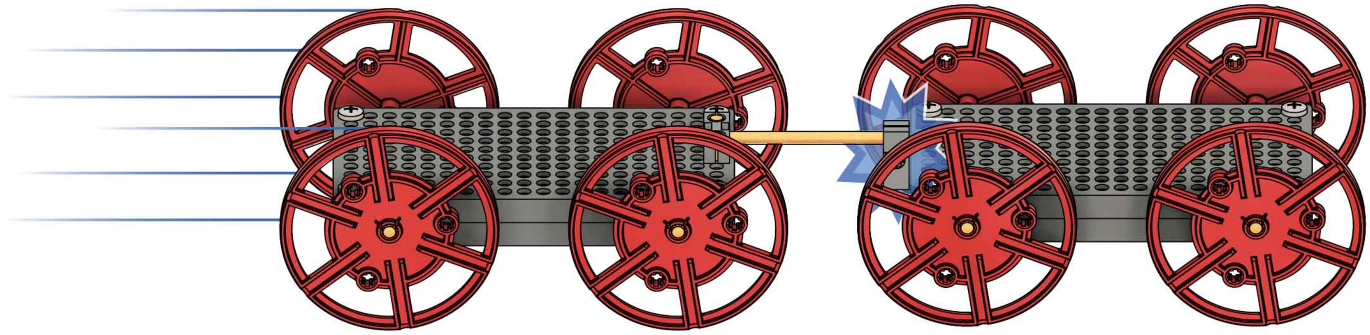
MOMENTUM LAB ADVANCED SAIL CAR

TeacherGeek

Name:________________________________

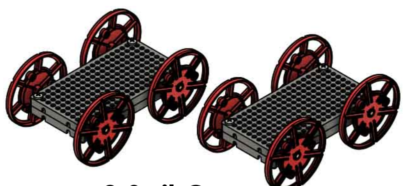
Check out the **Lab Set-Up Video** by scanning the QR Code or going to **teachergeek.com/sailcar**

What's momentum, and how does it affect collisions? Crash some cars to find out!

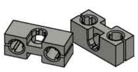


LAB SUPPLIES

TeacherGeek Supplies

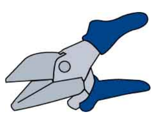


2 Sail Cars
(no sails)



2 Blocks

1 Dowel
30 cm (12 in)



Multi-Cutter

Other Supplies

- **Scale**
  grams (0.1 oz)
- **Tape**
- **1 Weight**
  100-200 g (4-7 oz)

- **2 velocity sensors**

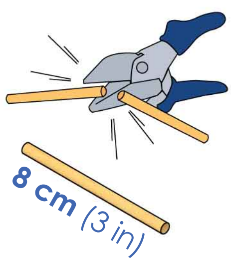
  OR
- **1 velocity sensor & 2 magnets**
  (to make the cars stick together on impact)

For recommended sensors, see p. 3.

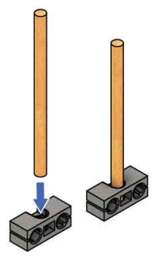
BUILD A RAM

Build a ram for <u>one</u> of your cars to get more accurate collision data.

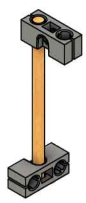
1. **Cut** an **8 cm** (3 in) **dowel**.



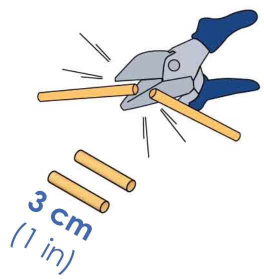
2. **Wiggle** or tap the cut **dowel into** a **block**.



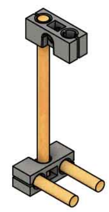
3. **Push** or tap another **block onto** the **dowel**, as shown.



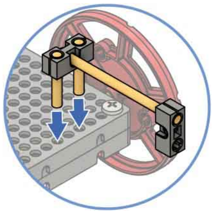
4. **Cut two 3 cm** (1 in) **dowels**.



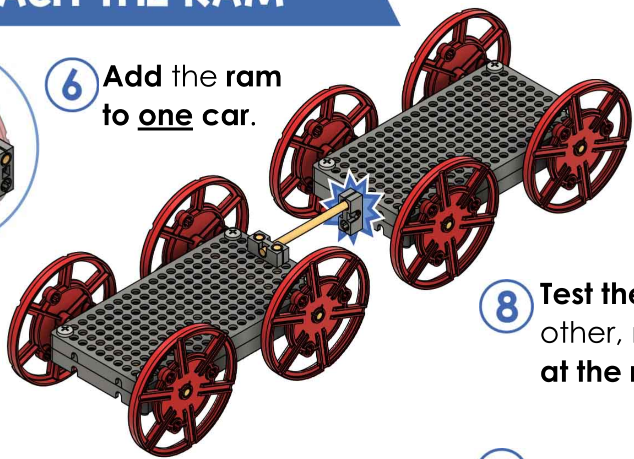
5. **Push** the **dowels into** the **block**, as shown, to finish your ram.



ATTACH THE RAM

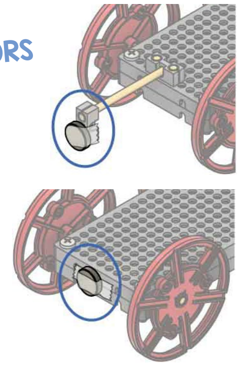


6. **Add** the **ram** to <u>one</u> **car**.



SKIP IF USING 2 SENSORS

7. **Tape** a **magnet to each car** so they stick together when they collide.

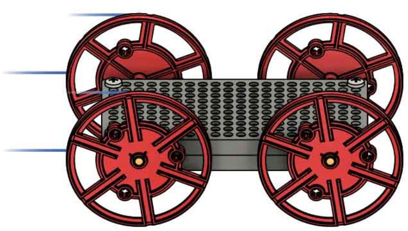


8. **Test the cars**. Push one into the other, making sure they **contact at the ram**, not the wheels.

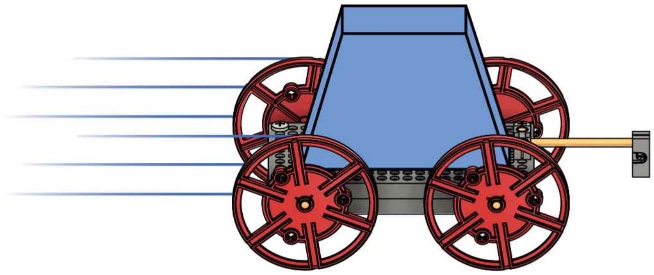
9. **Adjust** your **design** if necessary.

WHAT'S MOMENTUM

Momentum **is how difficult it is to stop a moving object. It is based on how quickly an object is moving and how much mass it has.**



This car has **little momentum** because it has little mass or velocity.



This car has **more momentum** because it has more mass and velocity.

Calculating Momentum

Momentum is typically represented by the letter **p**. To calculate momentum, multiply mass and velocity.

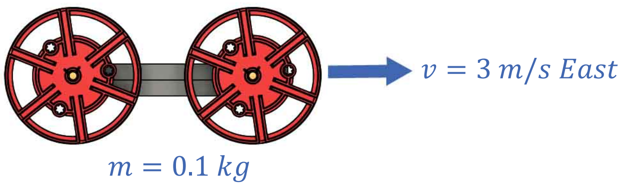
$$p = mv$$

Momentum is a vector quantity – it has both magnitude and direction. The direction of the momentum is the direction of the velocity.

Momentum has units of $kg * m/s$.

Example

A 0.1 kg car is traveling East at 3 m/s.



$$p = mv$$

$$= (0.1\ kg) * (3\ m/s\ East)$$

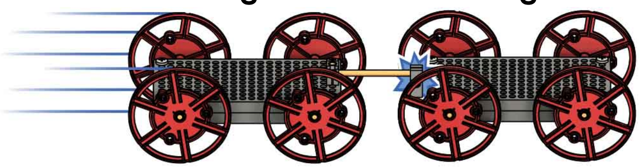
$$p = 0.3\ kg * m/s\ East$$

momentum

MAKE OBSERVATIONS

What happens to momentum during a collision?

10 **Push** the **car with** the **ram into** the **other car**.



11 How did the collision affect the momentum of the striking car? Did momentum increase, decrease, or stay the same? Explain.

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12 How did the collision affect the momentum of the car being struck? Explain.

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13 Create a hypothesis about what happens to momentum during a collision.

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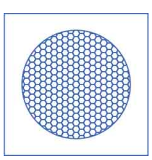
ADD SENSORS

Option A: One Sensor and Magnets

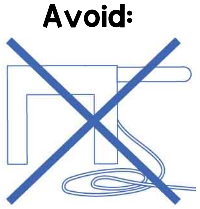
Set up the sensor to measure the velocity of the striking car. Be careful to keep the magnets away from the sensor and all other electronic devices.

Recommended:


PocketLab


Ultrasonic or Infrared

Avoid:


Photogates

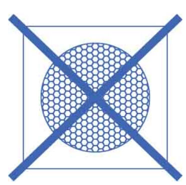
Option B: Two Sensors

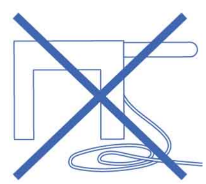
Set up your sensors to measure the velocity of each car.

Recommended:


PocketLab

Avoid:


Ultrasonic or Infrared


Photogates

TRIAL 1

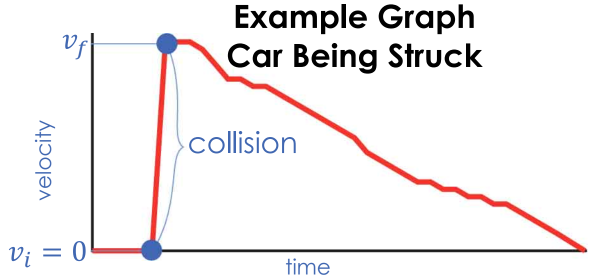
Does the data support your hypothesis?

14 Perform another collision between the cars, but this time, measure their velocities.

$\boldsymbol{v_i}$ – initial velocity before collision
$\boldsymbol{v_f}$ – final velocity after collision (if using magnets, this is the same for both cars)

Example Graph Striking Car

Example Graph Car Being Struck



m	v_i	v_f

m	v_i	v_f
	0	

15 Now calculate each car's momentum and kinetic energy.

Striking Car

p_i	p_f

K_i	K_f

Momentum

$$p = mv$$

Kinetic Energy

$$K = \frac{1}{2}mv^2$$

Car Being Struck

p_i	p_f

K_i	K_f

16 Finally, calculate the momentum and kinetic energy of the system.

To find the momentum of the system, add the momentum of its parts (the cars).
Do the same for kinetic energy.

System Momentum

p_i	p_f

System Kinetic Energy

K_i	K_f

17 Does the data support your hypothesis from Step 13? Explain.

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CONSERVATION OF MOMENTUM

Your data should have shown little change in the system's momentum.

As long as there's no external force, a system's momentum should be conserved during a collision. The total momentum should not change. This is called the Conservation of Momentum, and it comes from Newton's Laws (shown on p. 6).

18. Find the percent change for the system's momentum in Trial 1.

$$(\%\ change) = \frac{p_f - p_i}{p_i} * 100\%$$

$\%\ Change$

19. Does the data from Trial 1 support Conservation of Momentum? Reference the percent change in your explanation.

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CONSERVATION OF ENERGY

Your data probably showed the system's *kinetic* energy decrease, and that's OK.

In a collision, kinetic energy can be conserved or transformed into other forms of energy. Collisions are divided into three categories.

Elastic Collisions

If the kinetic energy of a system is conserved during a collision, the collision is elastic.

Inelastic Collisions

If the kinetic energy of a system is not conserved during a collision, the collision is inelastic.

Completely Inelastic Collisions

If the colliding objects stick together after the collision, the collision is completely inelastic.

20. Find the percent change for the system's kinetic energy in Trial 1.

$$(\%\ change) = \frac{K_f - K_i}{K_i} * 100\%$$

$\%\ Change$

21. Was the collision from Trial 1 elastic, inelastic, or completely inelastic? Explain.

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OPTIONAL

MOMENTUM & NEWTON'S "LAWS"

Wonder how momentum comes from Newton's Laws? Here's the math!

Let's start by looking at Newton's Second "Law," $F = ma$. If we do some algebra, this Law can give us information about momentum – we just need to make mv show up in the equation.

$$F = ma$$

Replace a with $\frac{v_f - v_i}{t}$ — Acceleration is change in velocity over time.

$$F = m\frac{v_f - v_i}{t}$$

Multiply both sides by t — mv is the formula for momentum (p).

$$Ft = m(v_f - v_i)$$

Distribute m

$$Ft = mv_f - mv_i$$

Replace mv with p

$$Ft = p_f - p_i$$

Replace $p_f - p_i$ with Δp — $Final - Initial$ is how you calculate change. Δ represents change.

$$Ft = \Delta p$$

So force multiplied by time, Ft, gives us the change in momentum, Δp,(called ***impulse***).

When your cars collide, they exert equal and opposite forces on each other (Newton's 3rd "Law"), so the force of car 1 on car 2 equals the force of car 2 on car 1.

$$F_{1\,on\,2} = -F_{2\,on\,1}$$

Multiply both sides by t — The cars exert forces on each other for the same amount of time.

$$F_{1\,on\,2}t = -F_{2\,on\,1}t$$

Replace Ft with Δp — This is the relationship we found from Newton's Second "Law."

$$\Delta p_1 = -\Delta p_2$$

Add Δp_2 to both sides

$$\Delta p_1 + \Delta p_2 = 0$$

Replace $\Delta p_1 + \Delta p_2$ with Δp_{system} — Our system is the two cars. So if you add the change in momentum for both cars, you get the change of the system.

$$\Delta p_{system} = 0$$

So using Newton's Laws, we see that the momentum of a system does not change during a collision inside that system.

TRIAL 2

What if the striking car has more mass?

22 Secure weights to the striking car to increase its mass, then perform another trial. 100 to 200 g of weights is recommended (3.5 to 7.0 oz).

Striking Car

m	v_i	v_f

p_i	p_f

K_i	K_f

Car Being Struck

m	v_i	v_f

p_i	p_f

K_i	K_f

System Momentum

p_i	p_f	$\%$ $Change$

System Momentum

p_i	p_f	$\%$ $Change$

TRIAL 3

What if the car being struck has more mass?

23 Transfer the weights from the striking car to the car being struck, then perform the final trial.

Striking Car

m	v_i	v_f

p_i	p_f

K_i	K_f

Car Being Struck

m	v_i	v_f

p_i	p_f

K_i	K_f

System Momentum

p_i	p_f	$\%$ $Change$

System Momentum

p_i	p_f	$\%$ $Change$

CONCLUSION

24 Overall, does your data confirm the conservation of momentum? Justify your answer.

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25 Did changing the mass of either car affect the conservation of momentum?

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26 What were some sources of error for your measurements?

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27 Were any of your collisions elastic? If not, which was the closest to being elastic and why?

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28 When your cars collided inelastically, what happened to the kinetic energy? Be specific.

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29 Fill in the blanks below.

Both momentum and kinetic energy are calculated using ______________ and ______________.

Momentum is a ______________ quantity, while kinetic energy is a ______________ quantity.

In a collision, ________________ is always conserved, while ________________ is not.